V.S.Padma, Dr.N.Kumara Swamy, Dr.K.Ramamohan Reddy / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue4, July-August 2012, pp.2166-2171

Impact Of Urban Agglomeration On Ground Water Quality – A Case Study

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ABSTRACT

Groundwater is a vital and indispensable natural resource. The available surface water sources cannot fulfill the needs of an entire city owing to growing population and rapid urbanization. Thus groundwater is the only source in many areas while a necessary supplement in some areas. Therefore it is important to monitor groundwater quality.

Objective of this study is to assess impact of Urban Agglomeration on ground water quality in the fast developing areas surrounding Tirupati Municipal limits. Physico-chemical tests were conducted on groundwater samples collected from eight gram panchayaths. Variations in the concentrations of different groundwater parameters were studied over a period of two years.

Results showed all parameters to be within the maximum permissible limits except for high values of calcium and magnesium. But excessive calcium and magnesium contents do not have any adverse effects on the human health except as mild laxative and change the taste of water. The water is safe for consumption. Results also indicate strong correlation between total dissolved solids, alkalinity, total hardness and chlorides content in groundwater in the study area. These characteristics of groundwater are attributed by carbonates, bicarbonates, hydroxides and chlorides of calcium and magnesium.

Keywords **–** Groundwater, physico-chemical parameters, quality analysis, Tirupati, urbanization.

1. INTRODUCTION

Tirupati is a prominent pilgrim center in Chittoor district of Andhra Pradesh state It is a Municipal Corporation of 2,87,035 population as per 2011 census, with an Urban Agglomeration of population 1,72,950 extending beyond the Corporation limits. Tirupati and its urban agglomerations are geographically located between $13^{o}30^{1}$N to $13^{o}50^{1}$N latitudes and $79^{o}20^{1}$E to $79^{o}35^{1}$E longitudes.

Population projections for the city have indicated significant growth peripheral to the municipal limits. The areas outside Municipal limits depend solely on groundwater for their domestic, agricultural and industrial needs. The city also has to cope with the flow of pilgrims which fluctuates from 55,000 on a normal day to 100,000 on festive occasions (Draft City Sanitation Plan, 2011)[1]. Hence there is heavy dependence on groundwater. Groundwater is generally less susceptible to contamination when compared to surface water sources. But with increasing agricultural and industrial activities, and improper drainage systems, there is scope for contamination of groundwater.

Studies by Shirley Ballaney, et al, 2002 [2] and Janardhana Raju et al, 2006 [3] have shown that increase in population has led to over-exploitation of ground water and the heavy demand for land for residential and commercial development has resulted in encroachment of dried up water tanks in and around Tirupati. Groundwater quality analysis conducted by Uttama Reddy, 2008 [4] and Varaprasuna, 2010 [5] in certain areas of Tirupati Municipality have shown that the water quality parameters are within standard limits and safe for consumption.

Linear correlation analysis of groundwater quality conducted by Rajdeep Kaur et al, 2011 [6] and Srinivasa Rao et al, 2012 [7] have indicated that all the parameters are more or less correlated to each other, in a pattern characteristic to the geo-environmental conditions prevailing in the area of study.

2. STUDY AREA

The quality of ground water was examined in this case study by testing borewell sources from 8 gram panchayaths – Avilala, Chandragiri, Cherlopalle, Ithepalle, Karakambadi, Mamandur, Rajeevgandhi Nagar and Settipalle. These areas are from the four mandals of Tirupati (Urban), Tirupati (Rural), Renigunta and Chandragiri, which comprise a major part of Tirupati Urban Agglomeration, outside the Municipal limits.

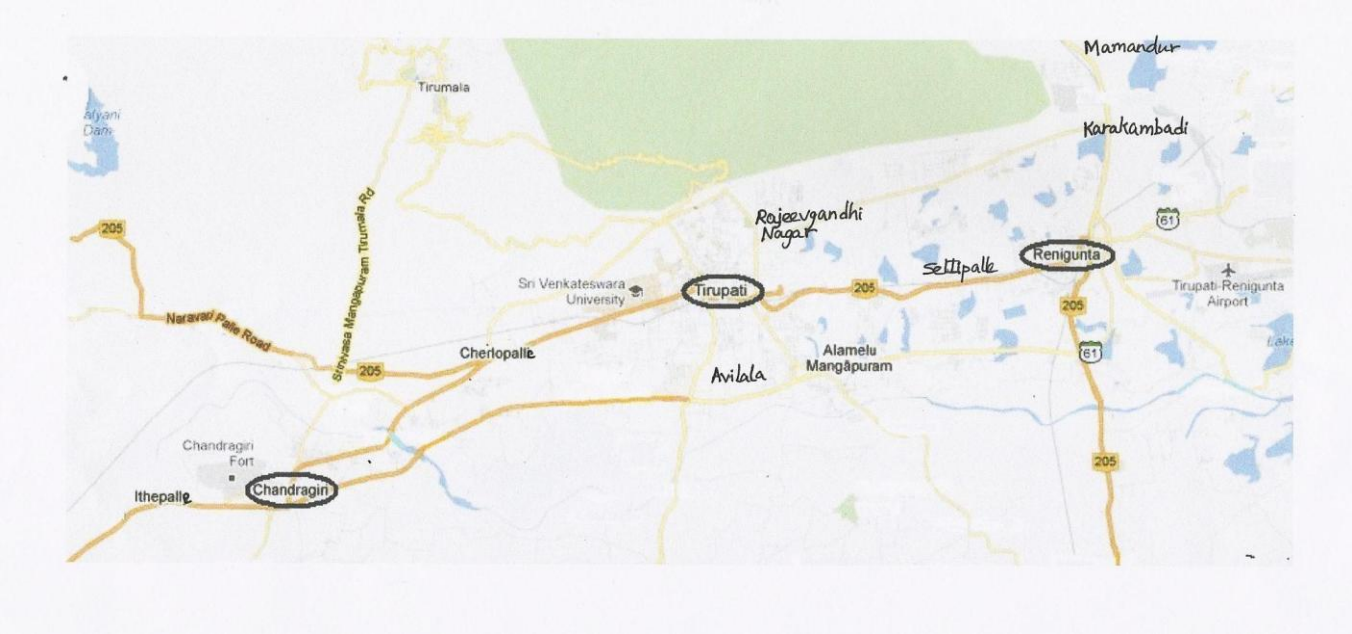

Fig.1. Location of study area in Tirupati Urban Agglomeration

3. Sampling And Analysis Techniques

The water samples were collected from each source in one litre capacity plastic cans and labelled with source code and date. The cans were rinsed with sample water before collecting for testing. pH was measured in field immediately after collection of samples. Remaining physico-chemical tests were conducted in the laboratory.

Total dissolved solids of water samples were measured within 2-3 hours of collection using Elico CM 183-EC-TDS Analyzer. Alkalinity, total hardness, calcium and chlorides were measured using standard titration methods. Hardness is mainly due to calcium and magnesium content. Hence concentration of magnesium was arrived from values of hardness and calcium content. Fluorides were measured using ion meter and iron content measured with ICS iron field test kit comparator box.

The sampling was done over a period of two years from January 2010 and December 2011 – pre-monsoon and post-monsoon. Analysis was conducted in the Water Quality Monitoring Laboratory, Rural Water Supply Department, Tirupati. The results obtained were compared with drinking water standards specified in IS 10500 : 1991[8] to assess potability of water in the study area.

4. RESULTS AND DISCUSSION

The results obtained from analysis of water samples are presented in Table 1 and Table 2 below, in terms of range (maximum – minimum) and average values.

pH expresses the intensity of acidic or alkaline condition of a solution. The permissible limits for pH of drinking water are 6.5-8.5. The pH values of samples in study area ranged from 6.8-8.2 which are within the permissible limits. The variation of pH value of ground water in study area is shown in Fig.2.

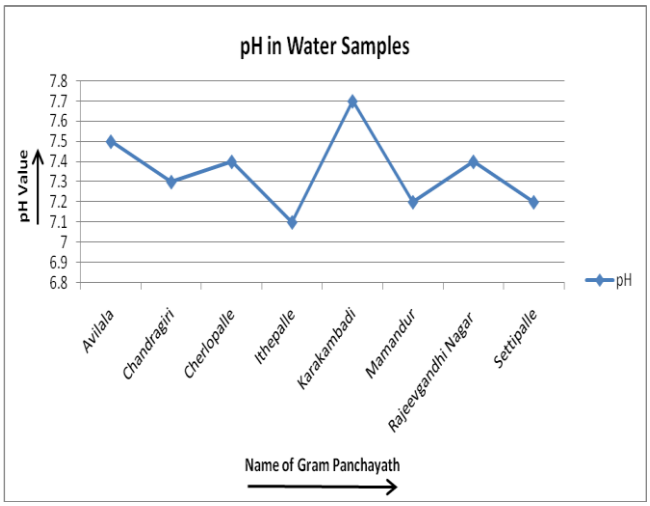

Fig.2. Average pH values at different locations

Table 1. Variations in values of pH, Total Dissolved Solids, Alkalinity, Hardness and Calcium Content

Name of Gram Panchayath	pH value		TDS (mg/l)		Alkalinity (mg/l)		Hardness (mg/l)		Ca (mg/l)	
	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range	Av.
Avilala	7.1-7.8	7.5	450-1600	1236	200-580	397	220-500	379	60-250	176
Chandragiri	6.9-8.2	7.3	240-1580	1093	140-500	322	120-500	352	80-420	167
Cherlopalle	6.8-8.2	7.4	523-1660	1193	240-600	379	300-530	408	140-230	186
Ithepalle	6.8-7.5	7.1	540-2000	1077	240-560	356	200-500	347	80-380	154
Karakambadi	7.0-8.5	7.7	590-1500	1156	240-480	372	150-500	368	50-220	147
Mamandur	7.0-7.4	7.2	1000-2000	1423	300-580	437	280-560	450	100-350	178
Rajeevgandhi Nagar	7.2-7.6	7.4	510-1560	1148	230-480	331	280-400	354	50-200	127
Settipalle	6.8-7.8	7.2	680-1750	1282	200-580	396	250-580	415	50-300	160
Highest desirable (as per IS 10500:1991)		6.5-8.5		500		200		300		75
Maximum permissible (as per IS 10500:1991)		-		2000		600		600		200

Table 2. Variations in values of Magnesium, Chloride, Fluoride and Iron Content

Name of Gram Panchayath	Mg (mg/l)		Cl (mg/l)		Fl (mg/l)		Fe (mg/l)	
	Range	Av.	Range	Av.	Range	Av.	Range	Av.
Avilala	50-300	183	85-436	290	0.2-1.0	0.7	0.1-0.1	0.1
Chandragiri	40-320	189	50-582	271	0.2-1.2	0.5	0.1-0.2	0.2
Cherlopalle	100-330	180	120-355	266	0.2-0.8	0.5	0.1-0.2	0.1
Ithepalle	40-355	176	85-512	243	0.1-1.0	0.5	0.1-0.2	0.1
Karakambadi	50-260	196	71-448	259	0.2-0.8	0.4	0.1-0.3	0.2
Mamandur	130-350	250	144-568	347	0.2-0.8	0.4	0.1-0.2	0.1
Rajeevgandhi Nagar	130-320	228	98-390	246	0.2-0.6	0.4	0.1-0.1	0.1
Settipalle	150-430	238	112-639	316	0.2-0.6	0.4	0.1-0.2	0.1
Highest desirable (as per IS 10500:1991)		30		250		1.0		0.3
Maximum permissible (as per IS 10500:1991)		100		1000		1.5		1.0

Total dissolved solids is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro granular suspended form. Total dissolved solids indicate the salinity behavior of groundwater. The maximum permissible limit for TDS in potable water is 2000 mg/l. The test results for TDS ranged from 240-2000 mg/l , with a few samples in Ithepalle and Mamandur having TDS of 2000 mg/l. This indicates that the ground water may be contaminated due to external sources of pollution.

Alkalinity of water is its capacity to neutralize a strong acid. The cause of alkalinity is the minerals which dissolve in water from soil. The maximum permissible limit for alkalinity in drinking water is 600 mg/l. High level of alkalinity is not harmful to human health but it imparts bitter taste to water. The samples had alkalinity within permissible limits, ranging from 140-600 mg/l, with some samples in Cherlopalle having maximum alkalinity of 600 mg/l.

Hardness is the property of water which prevents lather formation with soap and increases boiling point of water. Hardness of water mainly depends upon the amount of calcium or magnesium salts or both. The maximum permissible limit for hardness in potable water is 600 mg/l. The samples had hardness within permissible limit – ranging from 120-580 mg/l.

Calcium is naturally found in groundwater due to dissolving of calcium carbonates from rocks such as limestone, marble and calcite. The maximum permissible limit for calcium is 200 mg/l. Higher levels lead to hardness in water and formation of scales in pipes and boilers. Calcium levels in the test samples ranged from 50-420 mg/l.

Magnesium is dissolved into groundwater from rocks. The maximum permissible limit for magnesium is 100 mg/l. Higher levels do not pose any health hazards except for having a mild laxative effect and increasing hardness of water. Magnesium levels in the test samples ranged from 40-430 mg/l.

Chlorides are also naturally present in groundwater but high contents are indicative of contamination. Desirable limit for chlorides is 250 mg/l. In the absence of alternate source of water supply, maximum permissible limit for chlorides is 1000 mg/l. Beyond this limit water is unpalatable and corrosion occurs in pipes. High saline water intake causes hypernatraemia, loss of memory and expansion of head and liver. Test results indicate chloride levels ranging from 50-639 mg/l.

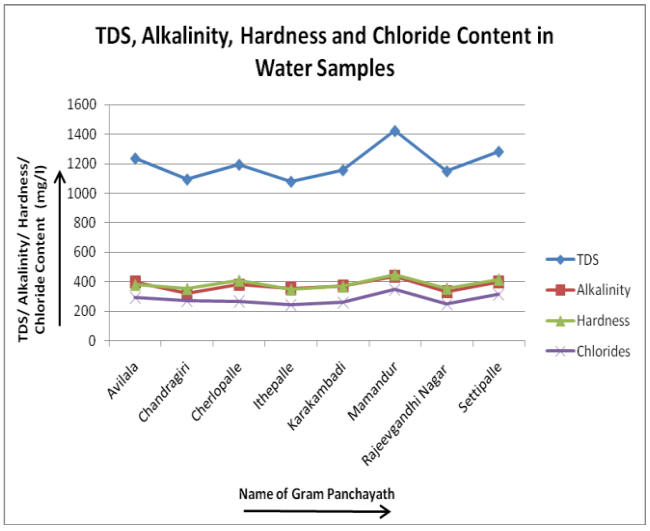

Fig.4. Average TDS, Alkalinity, Hardness and Chloride content at different locations

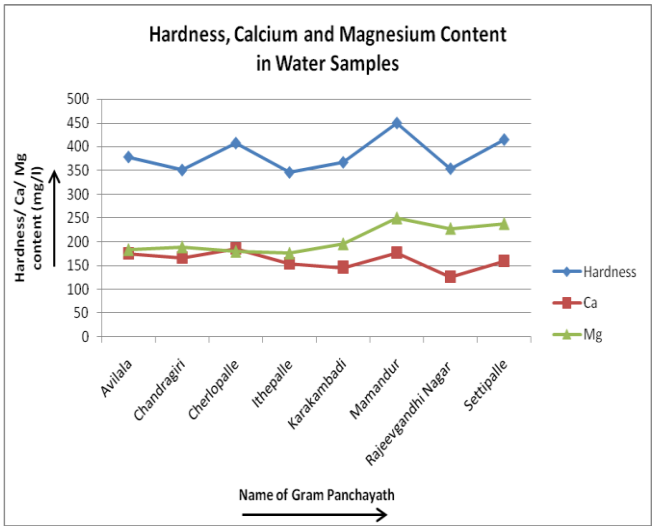

Fig.3. Average Hardness, Calcium and Magnesium content at different locations

Fluorides concentration in drinking water should not exceed 1.5 mg/l. Excess fluorides cause dental cavities and skeletal fluorosis. The samples were found to contain fluorides ranging from 0.1-1.2 mg/l.

Iron content in drinking water is permissible upto 1.0 mg/l. The samples were found to contain iron ranging from 0.1-0.3 mg/l. Long time consumption of drinking water with high concentration of iron can lead to liver disease namely haemosiderosis.

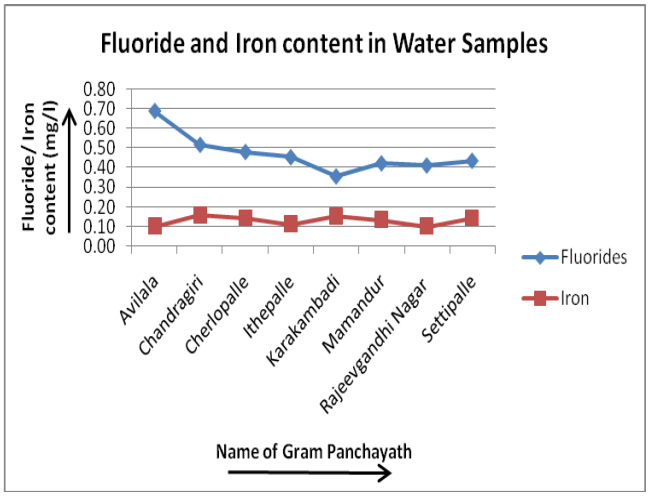

Fig.5. Average Fluoride and Iron content at different locations

Table 3. Average Values of all Parameters Tested from January 2010 to December 2011

Name of Gram Panchayath	pH value	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	Fl (mg/l)	Fe (mg/l)
Avilala	7.5	1236	397	379	176	183	290	0.69	0.10
Chandragiri	7.3	1093	322	352	167	189	271	0.52	0.16
Cherlopalle	7.4	1193	379	408	186	180	266	0.48	0.14
Ithepalle	7.1	1077	356	347	154	176	243	0.45	0.11
Karakambadi	7.7	1156	372	368	147	196	259	0.36	0.15
Mamandur	7.2	1423	437	450	178	250	347	0.42	0.13
Rajeevgandhi Nagar	7.4	1148	331	354	127	228	246	0.41	0.10
Settipalle	7.2	1282	396	415	160	238	316	0.44	0.14
Maximum permissible (as per IS 10500:1991)	6.5-8.5	2000	600	600	200	100	1000	1.50	1.00

Table 4. Linear Correlation Pattern Between Different Physico-chemical Parameters

	pH	TDS	Alkalinity	Hardness	Ca	Mg	Cl	Fl	Fe
pH	1								
TDS	-0.1713	1							
Alkalinity	-0.1308	0.9016	1						
Hardness	-0.2089	0.9366	0.8778	1					
Ca	-0.1492	0.4384	0.5574	0.5886	1				
Mg	-0.2613	0.7265	0.4378	0.6136	-0.1942	1			
Cl	-0.2799	0.9319	0.8194	0.8765	0.5255	0.6782	1		
Fl	0.0104	-0.0079	0.0692	-0.0930	0.4974	-0.4305	0.0900	1	
Fe	0.1810	0.0353	0.0046	0.2454	0.3134	0.0239	0.2104	-0.3727	1

Correlation between different parameters

The average values of all parameters at all locations, listed in Table 3, were observed for linear correlation and the pattern of correlation existing between them is shown in Table 4. Generally a correlation value of greater than 0.8 is described as strong and less than 0.5 is described as weak. Positive values indicate a relationship between the two parameters such that as values for one parameter increase, the values of the second parameter also increase and vice-versa.

Strong correlation is observed between TDS and alkalinity (0.9016), TDS and hardness (0.9366), TDS and chlorides (0.9319), alkalinity and hardness (0.8778), alkalinity and chlorides (0.8194), hardness and chlorides (0.8765).

From Table 4, it was observed that pH had a poor correlation with other parameters. This may be attributed to the different types of buffers (CO_3^{-2}, HCO_3^{-2}) normally present in the ground water.

Hardness had good correlation with magnesium (0.6136) compared with calcium (0.5886). The indicated contribution of magnesium to hardness was more than hardness causing cations. The amount of magnesium was present in the form of magnesium chloride (0.6782) in ground water.

Hardness and alkalinity correlation coefficient is 0.8778. This indicates that hardness causing calcium and magnesium present in water in the form of HCO_3^-, CO_3^- and OH^-.

The strong correlation between hardness and chlorides (0.8765) reveal that non-carbonate hardness is present in the groundwater.

TDS had strong correlation with alkalinity (0.9016), hardness (0.9366) and chlorides (0.9319), which indicates significant presence of carbonates, bicarbonates and chlorides in the ground water. The TDS comprise more of magnesium salts (0.7256) than calcium salts (0.4384).

Alkalinity had strong correlation with chlorides (0.8194) but weak correlation with calcium (0.5574) and magnesium (0.4378).

Fluoride had weak correlation with the remaining parameters and so did iron. Fluoride and iron were negatively correlated (-0.3727), which implies that an increase in fluoride content would mean

decreased presence of iron compounds in the groundwater.

5. CONCLUSION

A physico-chemical analysis of groundwater was carried out in eight areas of Tirupati Urban Agglomeration. Comparison of results with drinking water specifications in Indian Standards 10500:1991 indicate that:

- pH, fluorides and iron content in the groundwater are within permissible limits.
- TDS, alkalinity, total hardness and chlorides are close to the maximum permissible limits and hence the water has poor palatability.
- Concentration of calcium and magnesium in the groundwater are above permissible limits, but not harmful. These parameters contribute to hardness of water but the total hardness is within maximum permissible limit.
- The groundwater has both carbonate and non-carbonate hardness. The carbonate hardness can be removed by boiling but to remove the non-carbonate hardness an ion exchange process has to be used.
- In the absence of alternate sources, the quality of groundwater in the study area is safe for drinking purpose.
- A strong correlation pattern exists between TDS, alkalinity, hardness and chloride content in the groundwater.
- From the correlation pattern, an observed fluctuation in concentration of one parameter can be used to predict probable extent of fluctuation in the concentrations of the correlated parameters.

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